THE ROLE OF *Cerradomys subflavus* (RODENTIA, CRICETIDAE) AS SEED PREDATOR AND DISPERSER OF THE PALM *Allagoptera arenaria*

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ABSTRACT: Small rodents are among the most abundant vertebrate seed predators in the tropics and palm fruits are a rich source of energy for them. *Allagoptera arenaria* is a nurse plant species at restinga vegetation in southeastern Brazil. Forty-five adult *A. arenaria* were marked to estimate fruit crop size and seed predation by rodents. Two trapping sessions were carried out to identify the rodent seed predators. In addition, a fruit removal experiment was conducted to investigate the role of rodents as seed dispersers. Of the 7409 seeds collected, 24% were damaged by rodents. Predation rates ranged from 0 to 64% per plant and the number and proportion of damaged seeds increased significantly with crop size. In the removal experiments, 64% of the fruits were manipulated by rodents either in situ or away from palms: 16% were preyed in the same place, 29% were preyed following removal, 2% were dispersed and 12% were buried. Seed fate could not be identified for 5% of the seeds. *Cerradomys subflavus* was the only species caught and this fact together with its abundance in the study area and tooth marks left in the endocarps indicates that this rodent is the main seed predator of this palm. Considering this, *C. subflavus* should play a key role in *A. arenaria* population dynamics through the reduction of the total number of seeds that may be recruited. However, seed burial in sites favorable for germination suggests that this rodent can act also as seed disperser of this palm.

RESUMEN: El papel de *Cerradomys subflavus* (Rodentia, Cricetidae) como depredador y dispersor de semillas de la palma *Allagoptera arenaria*. Algunos pequeños roedores están entre los vertebrados depredadores de semillas más abundantes en los trópicos y las semillas de palmas son una rica fuente de energía para ellos. *Allagoptera arenaria* es una planta facilitadora de la vegetación en restingas en el sudeste de Brasil. Cuarenta y cinco palmas adultas de *A. arenaria* fueron marcadas para estimar la producción de frutos y la depredación de semillas por roedores. Dos sesiones de trampa fueron conducidas para identificar los roedores depredadores de semillas. Adicionalmente, un experimento de remoción de frutos fue conducido para investigar el papel de los roedores como dispersores de semillas. De las 7409 semillas colectadas el 24% fue dañada por roedores. Las tasas de depredación variaron de 0 a 99% por planta y el número y proporción de semillas dañadas aumentó significativamente con la producción de frutos. En los experimentos de remoción, 64% de los frutos fueron manipulados por roedores in situ o distante de las plantas madres: 16% fueron depredadas in situ, 29% fueron depredadas después de...
INTRODUCTION

Rodents are the most abundant mammals in the Neotropics (Glanz, 1990), acting as seed predators in diverse habitats. Due to their abundance and important contribution to total frugivores biomass, small rodents can prey on a large numbers of seeds (Adler and Kestell, 1998). Several studies showed that seed predation rates by these animals can be very high, reaching up to 90% in some cases (Bradford and Smith, 1977; Terborgh and Wright, 1994; Hoch and Adler, 1997; Ostfeld et al., 1997). Some species, however, can also act as important seed dispersers (Brewer and Rejmánek, 1999; Vieira et al., 2003; Xiao et al., 2004; Iob and Vieira, 2008; Yi and Zhang, 2008).

In the tropics, palm seeds are a rich source of energy for several animals (Zona and Henderson, 1989; Henderson, 2002). Insects, rodents and peccaries are the main consumers of palm seeds, influencing these plants at individual and population levels (Janzen, 1971; Kiltie, 1981; Silman et al., 2003; Silvius and Fragoso, 2003; Wyatt and Silman, 2004). Palm seed predation and dispersal by agoutis and squirrels has been widely reported (e.g. Galetti et al., 1992; Forget et al., 1994; Silva and Tabarelli, 2001; Silvius, 2002), while the role developed by small rodents is less known excepting for Heteromys spp. (Brewer and Rejmánek, 1999; Brewer, 2001) and Proechimys spp. (Forget, 1991; Hoch and Adler, 1997; Adler and Kestell, 1998).

Allagoptera arenaria (Gomes) O’Kuntze, locally known as “guriri”, is a small palm with subterranean stem (Fig. 1a). This palm is one of the dominant herbs in sand dunes in southeastern Brazil (Henderson et al., 1995; Pimentel, 2002), acting as a nurse species and facilitating the formation of the restinga (shrubby vegetation) (Zaluar and Scarano, 2000). Infrauctescences contain five to 129 one-seeded fruits (Grenha, 2006), 12 to 20 mm long and 10 to 13 mm in diameter with a sweet fibrous mesocarp (Henderson et al., 1995; Fig. 1b). At the study area A. arenaria fruits were found all year around, with fruiting peak from September to December (Grenha, 2006). This palm is probably an important food resource for the community of frugivores in this habitat because of its extended fruiting period and the production of a large amount of fruit (Grenha, 2006).

The consumption of A. arenaria fruits by vertebrates was described in laboratory conditions by the rodents Trinomys eliase and Akodon sp. and the marsupials Metachirus nudicaudatus, Philander frenata and Didelphis aurita (Leite, 1990). In nature, Gatti et al. (2006) reported that fruits of this palm were the most important item in the diet of the crab eating fox, Cercocyon thous, and the raccon, Procyon cancrivorus, occurring in more than 80% of the scats. Seed predation by invertebrates was reported by Grenha et al. (2008), who found that 30% of seeds were damaged by the bruchid beetle Pachymerus nucleorum. A. arenaria fruits have the potential to be dispersed by small rodents like many palms in Cerrado (Almeida and Galetti, 2007), but its predation and dispersal by these animals are...
poorly known in the field. In this work we
describe the predation and dispersal of
*Allagoptera arenaria* seeds by small rodents
and describe for the first time the use of this
palm by *Cerradomys subflavus* (Wagner,
1842).

**MATERIALS AND METHODS**

This study was carried out at the National Park of
“Restinga de Jurubatiba” (PNRJ, 22°-22° 23’ S,
41° 15’-41° 45’ W), which comprises approximately
14 451 ha in the municipalities of Macaé,
Carapebus and Quissamã, Rio de Janeiro state,
southeastern Brazil. In the study area the dry sea-
son ranges from August to September and the wet
season from October to April (Fig. 2). The sample
area is located near a ridge forest and consists of
patchy vegetation on bare sand (Araujo et al.,
1998). The rodent community found at the PNRJ
is composed by *Akodon cursor*, *Cerradomys
subflavus*, *Mus musculus*, *Nectomys squamipes*,
*Oxymycterus dasytrichus*, *Rattus rattus*,
*Trinomys eliasi* and *Sphiggurus* sp. (Bergallo et al.,
2004). Additionally, *C. thous* and *P. crancerivorus*,
which can act as long distance seed dispersers,
are also found in the area (Bergallo et al., 2004). The ro-
dent community is dominated by *Cerradomys
subflavus* (previously *Oryzomys subflavus*, Weskler
et al., 2006), which was twice as abundant as any
other species captured (Bergallo et al., 2004). This
rodent weights from 40 to 120 grams, and in Bra-
zil it is found at Caatinga, Atlantic Coastal Forest,
Cerrado and Pantanal Biomes (Emmons and Feer,
1997). At Restinga and Cerrado Biomes, this spe-
cies is found in all of vegetation types (Alho,
1981; Fonseca and Redford, 1984; Bergallo, 2004), breed-
ing uniformly throughout the year and usually
nesting in the ground (Alho and Pereira, 1985).

The first 45 adult palms found in a 0.5 ha area
were marked to the estimation of crop size and
predation by rodents. This area comprises typical
patches of *A. arenaria* and is surrounded by denser
vegetation. Adult palms were those that either were
reproductive at census time or showed evidence of
previous reproduction. The distance among selected
palms ranged from 1.0 to 50 m. In August 2003,
all the endocarps remaining on the ground beneath palms were removed. Each month from September 2003 to August 2005, endocarps within a 0.5 m radius of each palm were collected and taken to the laboratory to describe seed damage. For each palm, predation rates were estimated as the proportion of damaged seeds in relation to the total number of endocarps. Regression analysis was used to test whether the number and proportion of seeds damaged by rodents depends on the number of available seeds (crop size).

Two trapping sessions were carried out in October 2005 and December 2007 to identify the rodents that interact with *A. arenaria* seeds. In each session, eighty-two Sherman aluminium live traps (38 x 10 x 12 cm) were placed beneath 60 palms with signals of seed predation by rodents, including 33 of the marked ones, to maximize trapping success. Palms with one infructescence received a single trap while those with two or more infructescences received two traps. Each trap was baited with a piece of Bahia coconut (*Cocos nucifera*), peanut butter and three fruits of *A. arenaria*. Traps were placed in the afternoon and checked at the following morning. Two of the *C. subflavus* individuals caught in the first trapping night were taken to the laboratory to describe their feeding behavior and tooth marks left in the endocarps. After that, animals were released at the study area.

In order to understand the role of rodents as seed dispersers, a fruit removal experiment was conducted in March 2008. Groups of five threaded mature fruits were placed beneath 30 *A. arenaria* individuals spaced every 10 m. Fruits were collected in the field, taken to the laboratory for marking and placed in the field in the following morning. On each fruit a 5 mm metal ring was passed through a small hole made in the endocarp. A 30 m thread was tied to the metal ring and the spool of thread was placed inside a small container attached to the palm. This method has been used in other studies with small rodents and does not seem to affect seed removal and distances moved (Almeida and Galetti, 2007; Donatti et al. 2009). After 30 consecutive days in the field, seeds were categorized as not manipulated, preyed upon by rodents, dispersed (removed but not buried) or scatter-hoarded.

**RESULTS**

Of the 7409 seeds collected beneath parent palms, 1827 (24%) were preyed upon by rodents. Preyed seeds were found all year around and the number of damaged seeds per palm varied markedly (from 0 to 64% of seeds). Plants with larger crop sizes had more seeds damaged by rodents. Both the number ($R^2 = 0.79$, $F = 162.04, p < 0.0001$, Fig. 3a) and proportion ($R^2 = 0.24$, $F = 13.90, p < 0.001$, Fig. 3b) of seeds preyed upon by rodents increased significantly with crop size.
Most palms had the infructescence peduncle cut off indicating that rodents remove the whole bunch from plants before seed consumption. Strips of exocarp and mesocarp were found near damaged endocarps, indicating that rodents peel the fruits before endosperm consumption (Fig. 1c). Most of the tooth marks on *A. arenaria* fruits were made at the median region of the endocarp and no endosperm remains inside endocarps (Fig. 1d). The same pattern was observed in the seeds offered in the laboratory to the individuals caught. These individuals consumed unripe and mature fruits as observed in the field.

A trapping effort of 164 trap-nights resulted in the capture of nine *C. subflavus* individuals (a trapping success of 6%), five of them at the first trapping session and four at the second. No other small mammal species was caught. The rodents consumed all *A. arenaria* seeds used as bait and also the seeds offered in the laboratory, making feeding marks similar to those found in seeds collected in the field.

Of the 150 experimental fruits marked with thread, 36% were not manipulated by rodents and 64% were manipulated either in situ or away from palms. Seed fate could not be identified for 5% of the seeds. Forty-five percent of the seeds were preyed upon by rodents, 16% in the same place they were set and 29% following removal. Rodents dispersed 2% of the seeds, which were left on the soil surface, and buried 12% in the same place where they were set (Fig. 4). Buried seeds were found intact and with pulp between 2 and 6 cm deep in the soil and two of them were germinating. Removal distances were short, ranging from 0.2 to 4.7 m.

**DISCUSSION**

Predation by small rodents is an important factor of seed mortality in the tropics (e.g. DeMattia et al., 1994; Hulme, 1993; Adler, 1995; Vieira et al. 2003; Pinto et al., 2009), but few studies investigated the role of these animals in palm seed predation (e.g. Forget 1991; Brewer and Rejmanéck, 1999; Andreazzi et al., 2009; Donatti et al., 2009). Herein, we showed that these animals can damage a large proportion of *A. arenaria* seeds. Predation rates are not uniform among individuals; palms with larger crop sizes were attacked proportionally more than those with smaller crop sizes. This result suggests a lack of predator satiation, contrary to what has found in other studies involving rodent seed predation (e.g. Theimer, 2001; Romo et al., 2004; Briani and Guimarães, 2007).

The high consumption of *A. arenaria* seeds by rodents can be maintained by fruit production throughout the year (Grenha, 2006). The subterranean stem facilitates the access of small terrestrial rodents to fruits while still on the palm. Besides that, most infructescences reach the ground when mature due to fruit weight. The removal of fruits directly from the parent tree is rare in non-volant small mammals, excepting some arboreal species like squirrels (Maia et al., 1987; Galetti et al., 1992, Bordignon et al., 1996), as most animals consume fruits after they fall to the ground (Forget, 1991; Schupp, 1992; Vieira et al., 2003).

*Cerradomys subflavus* was the only species caught in this study and was the species most abundant sampled by Bergallo et al. (2004) in the same area, having an abundance two times higher than the second species more captured. These results plus the fact that the tooth marks left on the endocarps in the field were similar to those made by *C. subflavus* in laboratory suggest that this rodent is the most associated with *A. arenaria* seeds.

Seed removal experiments confirmed the efficiency of these small rodents as seed predators, as almost 50% of seeds were damaged.

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**Fig. 4.** Fate of *Allagoptera arenaria* seeds in removal experiments (see text) carried out in the National Park of Restinga de Jurubatiba, southeastern Brazil.
after fruit manipulation. Few intact seeds were carried away from palms and dispersal distances were short. Small dispersal distances are common for small rodents (Brewer and Rejmanek, 1999; Almeida and Galetti, 2007) and could have an impact in plant spatial distribution. In fact, *A. arenaria* has a clumped distribution in the study area and the short dispersal distances could be one of the factors responsible for this.

The fact that most removed seeds were killed suggests that this rodent does not play an important role in seed dispersal. However, seed burial beneath parent palms could favor the recruitment of new individuals. Seed burial cannot prevent beetle attack as it does in some other species (Smythe, 1989; Galetti et al., 2006) because bruchines are pre-dispersal predators on *A. arenaria* seeds (Grenha et al., 2008). Nonetheless, seed burial near palms can favor seedling recruitment in this harsh habitat as found for other restinga species (Zaluar and Scarano, 2000; Scarano et al., 2004). The shadow provided by crown and the organic matter provided by palm dead leaves could improve the microclimate for seed germination (Menezes and Araujo, 2000). Besides that, the fact that pulp is not removed before burial can also favor germination by reducing seed desiccation.

Vieira (2002) reported that *C. subflavus* was one of the main seed predators of dicots in Brazilian Cerrado, but the consumption of palm seeds by this rodent has not been documented before. In spite of the use of palm fruits by Oryzomyine rodents have been reported by other authors (Vieira et al., 2003; Pimentel and Tabarelli, 2004; Pinto et al., 2009) this is the first evidence of scatter-hoarding behavior in this group.

*Cerradomys subflavus* may play a key role in *A. arenaria* population dynamics by reducing recruitment from seeds. Nonetheless, as new individuals of *A. arenaria* are recruited primarily from seeds (Scarano et al., 2004), the role developed by this rodent in the seed dispersal and burial of this palm cannot be neglected and demands further investigation.

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